# NOTES ON REGRESSION IN A PURE LINE OF PLANT LICE.

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In a previous number of the BIOLOGICAL BULLETIN[1] the writer published the results of some selections made within a pure line of plant lice. These were made in an attempt to increase and to decrease the length of the third segments of the antennæ in comparison with that of the fourth segments. The species used was our common European grain aphis, *Aphis avenæ* Fab.; and the results obtained up to that time, which included the first ten generations, appeared to show that selections from extreme variants did not alter the mean as obtained for the line without selection. These results were in accord with the results obtained by other workers in pure lines.

But it also appeared that the mean of the offspring of the variants selected reverted not to the mean of the line, or strain, but that it would swing pendulum-like much beyond this mean only to be brought back to the former side of the mean-of-the-strain base line in the next generation.

Since the publication of this former paper I have tested further this aspect of regression by selecting from opposite extremes in alternating generations. These selections were begun in the ninth filial generation, and continued into the fifteenth, including in all seven generations. I will now give briefly the results of these selections.

An individual with the remarkably high index of 2.82 : 1 (*i. e.*, the third segments of the antennæ were two and eighty-two hundredths times as long as the fourth segments) was selected as the stem progenitor from among the individuals of the $F_8$ fraternity,—which fraternity has been mentioned in my previous paper. From this individual there were reared five wingless adults which gave a fraternal mean of 1.75 : 1, *i. e.*, .05 below the mean of the strain which was 1.80 : 1. From the $F_9$ fraternity,

[1] Vol. XXVI., No. 1, January, 1914.

$F_9$16 was selected for carrying on the strain. It had an index of 1.58 : 1, and gave a fraternity with a mean of 1.82 : 1. From this $F_{10}$ fraternity, $F_{10}$4 with an index of 2.11 : 1 was chosen. The mean for its offspring was 1.89 : 1. From this $F_{11}$ fraternity, $F_{11}$4, formula 1.78 : 1, was isolated. It gave the $F_{12}$ fraternity, with a mean of 1.84 : 1. $F_{12}$6, formula 1.98 : 1, gave the $F_{13}$ fraternity, with a mean of 1.85 : 1. $F_{13}$4, the next parent selected, had an index of 1.67 : 1, and gave the $F_{14}$ fraternity with a mean of 1.69 : 1. From the $F_{14}$ fraternity the last selection was made. $F_{14}$1, formula 1.70 : 1, was isolated, and gave the $F_{15}$ fraternity with 1.81 : 1 as a mean.

In each of these selections the individual with either the highest or the lowest antennal index was isolated in order to obtain the next generation of descendants. As has been stated, the index as obtained without selection for the mean of the pure line was 1.80 : 1. Thus it will be noticed that in four of the seven selections made, the offspring of the extreme variant gave a fraternal mean which showed a regression beyond the mean of the strain. In the case of the other three selections the regression of the fraternal mean did not reach the mean of the strain.

In order to observe more fully the effects of selection and the action of regression, I will give here in the order of their ratios the antennal formulæ of the eighteen parents thus far obtained in the first fifteen generations of the pure line[1] together with the indices representing the fraternal means of their offspring. They are as follows:

| Indices for Parents. | Indices for Fraternal Mean of Offspring. |
|---|---|
| 1.66 | 1.88 |
| 1.67 | 1.77 |
| 1.67 | 1.83 |
| 1.67 | 1.69 |
| 1.70 | 1.81 |
| 1.77 | 1.77 |
| 1.77 | 1.71 |
| 1.78 | 1.84 |
| 1.79 | 1.95 |
| 1.80 | 2.01 |
| 1.85 | 1.80 |
| 1.86 | 1.77 |

[1] Two of the parents which had antennal indices such as to suggest mutations or abnormalities are omitted.

| | |
|---|---|
| 1.86 | 1.85 |
| 1.88 | 1.80 |
| 1.89 | 1.93 |
| 1.98 | 1.85 |
| 2.08 | 1.66 |
| 2.11 | 1.89 |

If we now plot these results by using a scheme similar to that employed to illustrate Galton's law of regression we shall have the following graphical representation (Fig. 1) of the regression as found up to the fifteenth generation in this pure line of plant lice.

Here the heavy line represents the mean-of-the-strain base line, and is placed at 1.80. The lighter parallel lines above and

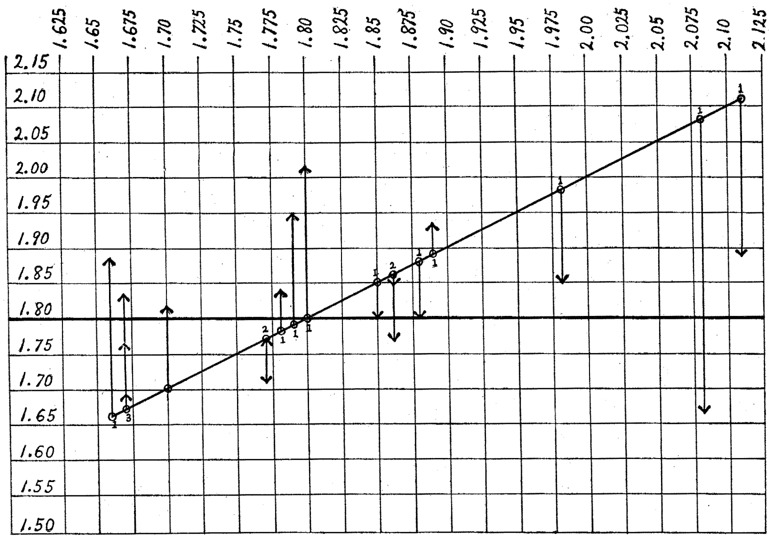


FIG. 1.—Diagram showing iegression within a pure line of *Aphis avenæ* Fab. The heavy base line at 1.80 represents the position of the mean of the line, or strain. The small circles represent the positions of the parents according to the index of their third and fourth antennal segments; the small number placed by each circle shows the number of parents with the antennal index indicated by the circle; the arrow-heads represent the positions of the mean of the fraternities obtained from these various parents. The arrows show the amount of regression.

below this base line each represent an increase or decrease in the index ratio for the third and fourth antennal segments of five one-hundredths. Similarly one of the vertical lines represents the mean-of-the-strain base line, and is marked 1.80; and on

each side of it other parallel lines are laid off at equal distances. Each of these represents a difference of 0.025 in the index ratio for the antennal segments considered.

On this diagram small round circles have been placed representing the position of each of the eighteen parents according to their antennal index-ratio. These naturally form a straight line which is indicated. Now the mean index of the offspring of each parent is represented by an arrow-head, placed immediately above or below, as the case may be, the circle indicating the index of the parent. A line connecting these two points forms the arrow which indicates the actual amount of regression in each instance. In three instances we have more than one stem parent with the same index-ratio, hence in these cases the arrows showing regression are superimposed.

It is observed that in some instances the regression is not to the mean of the strain, and in other instances it is much beyond the mean of the strain; while in two instances there is no regression at all, but a deviation from the mean of the strain even greater than that that existed before in the parent.

In order to compute the average amount of regression we may arrange in parallel series the deviations as shown in the indices of the various parents from that of the mean of the strain, and the deviation shown by the average for the indices of their progenies. This is here done, the mean of the strain being given as zero and the deviation found in the various antennal ratios from this mean being given in hundredths, plus or minus, as the case may be.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Deviations in indices of parents | − 14 | − 13 | − 13 | − 13 | − 10 | − 3 | − 3 | − 2 | − 1 |
| Average deviation found in offspring.................... | + 8 | − 3 | + 3 | − 11 | + 1 | − 3 | − 9 | + 4 | + 15 |
| Deviations in indices of parents | 0 | + 5 | + 6 | + 6 | + 8 | + 9 | + 18 | + 28 | + 31 |
| Average deviation found in offspring.................... | + 21 | 0 | − 3 | + 5 | 0 | + 13 | + 5 | − 14 | + 9 |

This relation of the regression can be expressed in the form of fractions by taking in each instance the difference in the deviation of the offspring from that of the parent, for the numerator; and the deviations of the parent itself in each instance as the denominator. These will then be:

+ 22/14, + 10/13, + 16/13, + 2/13, + 11/10, 0, − 6/3, + 6/2, + 16/1, + 5/5, + 9/6, + 1/6, + 8/8, − 4/9, + 13/18, + 42/28, + 22/31.

We may also express this series in the form of decimals, which will be as follows:

1.57, .76, 1.23, .15, 1.10, 0, − 2.00, 3.00, 16.00, 1.00, 1.50, .16, 1.00, − .44, .72, 1.50, .70.

These fractions added together and divided by their number should give us the average amount of regression. If the regression is according to Galton's law the decimal should be 0.333; if according to Johannsen's predictions, that is if the regression is complete, it should be 1.00. The figure which we actually obtain by adding these fractions and dividing by their number is 1.64. In other words, the regression is more than complete, or beyond the mean of the strain. However, it should be noted that the number of individuals included in this computation is too small to permit the results to be conclusive. Yet the results show that regression in a pure line of a parthenogenetic form does not follow Galton's law, also that there appears to be some justification in the contention made in a previous paper of mine, that regression under these conditions is somewhat pendulum-like, swinging beyond the mean of the strain, or line.